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PATENT
Case No. N0080US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	09/729,939
Applicant	:	Rajashri Joshi et al.
Filed	:	December 5, 2000
Titled	:	Method and System for Representation of Geographic Features in a Computer-based System

DECLARATION UNDER 37 CFR 1.131

The undersigned, RAJASHRI JOSHI, OLE HENRY DORUM and VIJAYA ISRANI, hereby declare that:

1. We are co-inventors of the invention described and claimed in the above-identified patent application.

2. Before August 25, 2000, we invented a new method for representing geographic features. Part of this new method included, fitting a polynomial spline to the a geographic feature by applying a least squares approximation to data points specifying latitude and longitude coordinates to generate a plurality of control points for the polynomial spline.

3. Before August 25, 2000, we prepared an Invention Disclosure Statement Form describing our invention. We filed the Invention Disclosure Statement Form with the Legal Department of the assignee of the subject patent application. A redacted copy of the Invention Disclosure Statement is attached hereto (Exhibit 1).

4. The section entitled "Detailed Description of Invention" beginning on page 3 of the attached Invention Disclosure Statement Form discloses the elements of our invention recited in paragraph 2., above.

5. All statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

RAJASHRI JOSHI	6/30/2006 Date
OLE HENRY DORUM	7/10/2006 Date
VIJAYA ISRANI	6/30/06 Date

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INVENTION DISCLOSURE STATEMENT

(Return to Legal Department)

IDS # [redacted]
(to be filled out by Legal Dept.)

Shorthand Name for Invention: Polynomial Spline Representations for Road Geometry

Developers Who Contributed to Invention:
1. Rajashri Joshi
2. Vijaya Israni
3. Henry Dorum
4. -----
5. -----
6. -----
7. -----
8. -----

Date (or Month) on Which Development Began:	[redacted]
If Known, First Date (if any) on Which Development was:	
(a) described in a CONFIDENTIAL document released outside of NavTech	
(b) described in a CONFIDENTIAL conversation with a non-NavTech employee	
(c) described in a NON-confidential document released outside of NavTech	
(d) described in a NON-confidential conversation with a non-NavTech employee	
(e) included in any version of a product released outside of NavTech	
(f) used internally at NavTech in the normal course of operations:	

Summary of Invention:

New space-efficient methods for accurately representing and storing road (polyline) geometry using polynomial splines (B-splines and Catmull-Rom Spline).

Advantages of Invention (to the extent known):

These methods provide a more accurate and more efficient representation of road geometry which may be of great use in future ADAS applications where high precision data is required, but storage is limited. The space savings is approximately 35% for three of the methods, and 10% for the fourth.

This invention also provides a methodology for automatically computing the alternate spline representations.

Detailed Description of Invention
- **describe function(s) performed**
- **describe with particularity the way in which each function is achieved (e.g., if the invention is a process, describe each step of the process):**

Please attached document 'Detailed Description of Invention'.

Please check the appropriate box:

☐ **No design documents exist**

☒ **The following design documents exist (and copies are attached):**

Analysis of Curve Representation Methods
Analysis of Curve Representation Methods presentation slides
Also available at:
R:\Product_Dev\ARES\Collaborative\Department\Ares\ADAS\REPORTS\PROJECTCurve1_2.doc
R:\Product_Dev\ARES\Collaborative\Department\Ares\ADAS\REPORTS\PROJECT\Curveslides.ppt

Signature: Rajashri R. Joshi
(of preparer-developer)

Date: [redacted]

[redacted] **CONFIDENTIAL**

Type Name: Rajashri Joshi

Signature(s) of Contributing Developers:

1. Name: Ole H. Heil Date: [redacted]
2. Name: Vijaya Sorrani Date: [redacted]
3. Name:__________ Date:__________
4. Name:__________ Date:__________
5. Name:__________ Date:__________
6. Name:__________ Date:__________
7. Name:__________ Date:__________

Detailed Description of Invention

The four polynomial spline representation methods that have been developed are described briefly below. (For more details, please see the attached documents "Analysis of Curve Representation Methods" and the accompanying slide presentation)

Overview of Invention: Road geometry is currently represented by a set of node and shape point latitude/longitude pairs, with a piecewise linear interpolation between points. For ADAS application, it is necessary for the data to have much higher accuracy than for navigation applications such as SDAL. Of course, the accuracy of the data can be made arbitrarily high by simply increasing the data density, i.e., by using more shape points to represent each segment. However, this increases storage requirements of the database. Described below is a new methodolgy for representing road geometry more accurately and more efficiently in terms of polynomial spline control points.

A *polynomial spline* is a piecewise polynomial function which is determined completely by a set of *control points* (and in some cases, a set of additional parameters called *knots*.) We use the shape points of each segment to compute the corresponding polynomial spline control points. Once the control points have been computed, the shape points can be discarded, and only the control points need to be stored.

Since one of the primary goals in developing new representations of map data is to obtain an accurate space efficient representation, in general we want the total number of control points to be smaller than the total number of shape points. In this case, the computed splines will not, in general, interpolate all of the shape points; rather, all of the methods described below involve the computation of the spline control points which *approximate* the given data (shape points) in a Least-Squares sense (this means that the Mean-Squared Error between the computed spline and the shape points is minimized.) The accuracy of the approximation improves as the number of control points is increased. Hence, in all of the following methods, the number of control points (and hence the accuracy of the representation) is configurable.

The four methods were tested on small test track databases. The space savings is currently approximately 35% for the first three methods and 10% for the fourth method. An example clip is shown below for each method (More examples can be found in the design documents.) The Shape Points are shown in blue, while the computed control points are indicated in red. From these examples it can be seen that storage of the control points instead of the shape points does indeed result in a space savings.

1. **Uniform B-Spline LS Fit Representation:** This method involves computation of the Uniform B-spline which minimizes the Mean Squared Error between the computed spline and the specified shape points, as well as the *bearing values* at the end nodes, for a specified (configurable) number of control points. Furthermore, by appropriately, weighting the end nodes, the spline can be forced to approximate the end nodes arbitrarily closely. Example: See Figure 1.

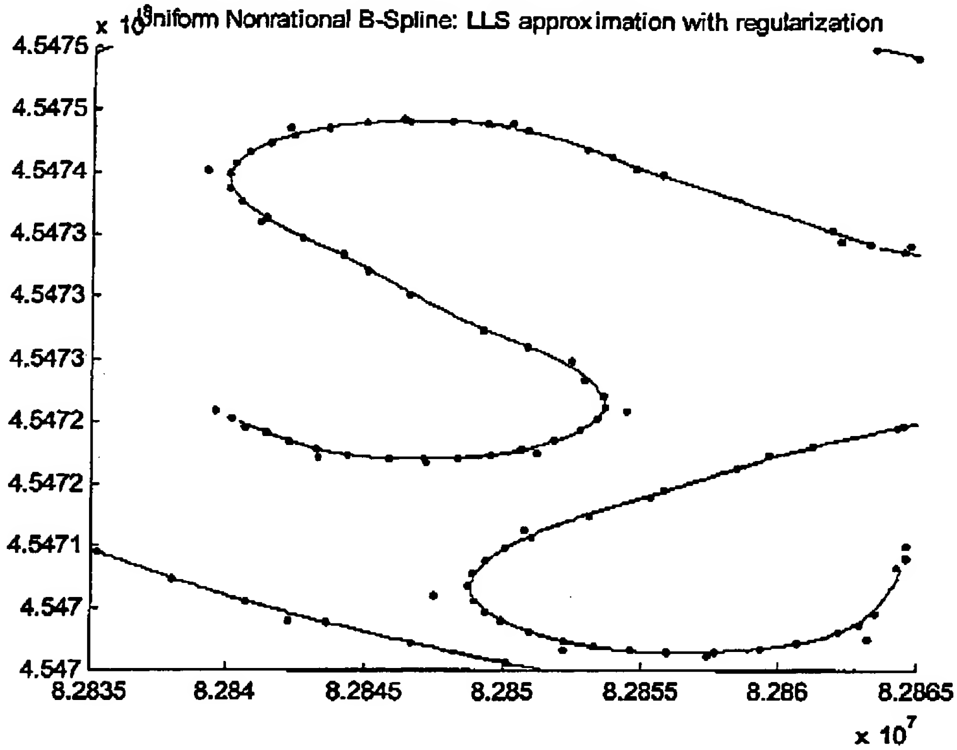

Figure 1

2. **Uniform B-Spline LS Fit Alternative Representation**: This method is similar to method 1 above, but long straight segments of each polyline are represented using the conventional method (storing lat/long values of endpoints). Continuity is ensured at the points at which the straight sections and curved sections of the polyline meet, by incorporating this information into the LS Fit computation. Furthermore, the degree to which this continuity is enforced is weighted by a configurable factor. Example: See Figure 2.

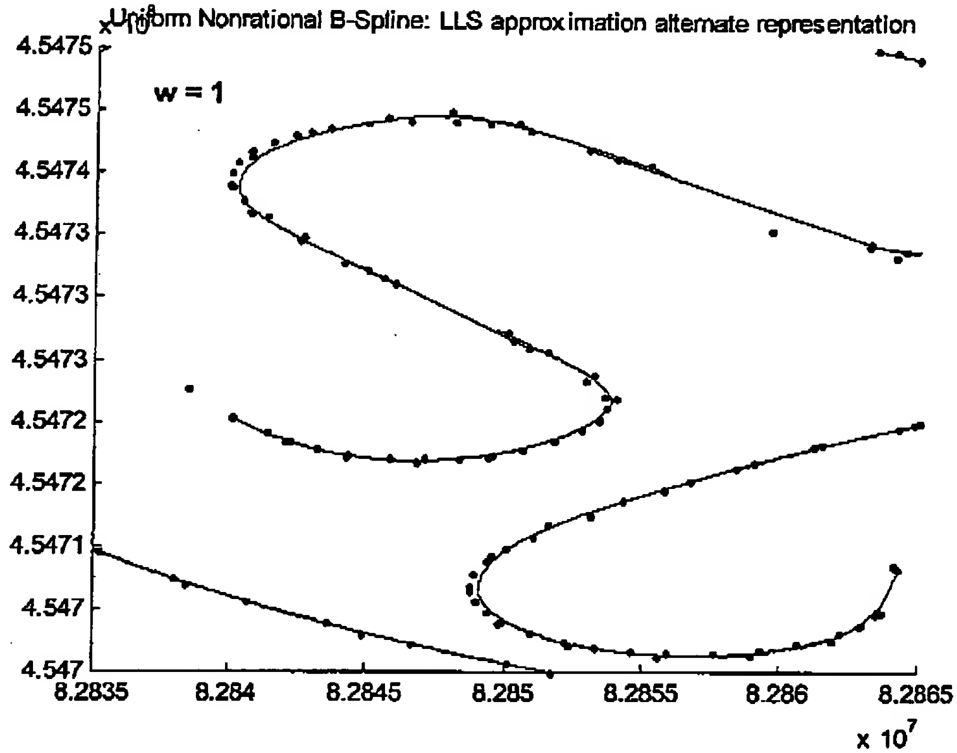

Figure 2

3. **Catmull-Rom Spline LS Fit Representation**: This method involves computation of the Catmull-Rom spline which minimizes the Mean Squared Error between the spline and the specified shape points, for a specified (configurable) number of control points. The main advantage of this method is that the control points of the spline actually lie on the spline (this is not the case with the B-splines). On the other hand, the Catmull-Rom spline is 'less' continuous than the B-splines, and does not have other properties (convex hull,) which the B-spline possesses. Example: See Figure 4.

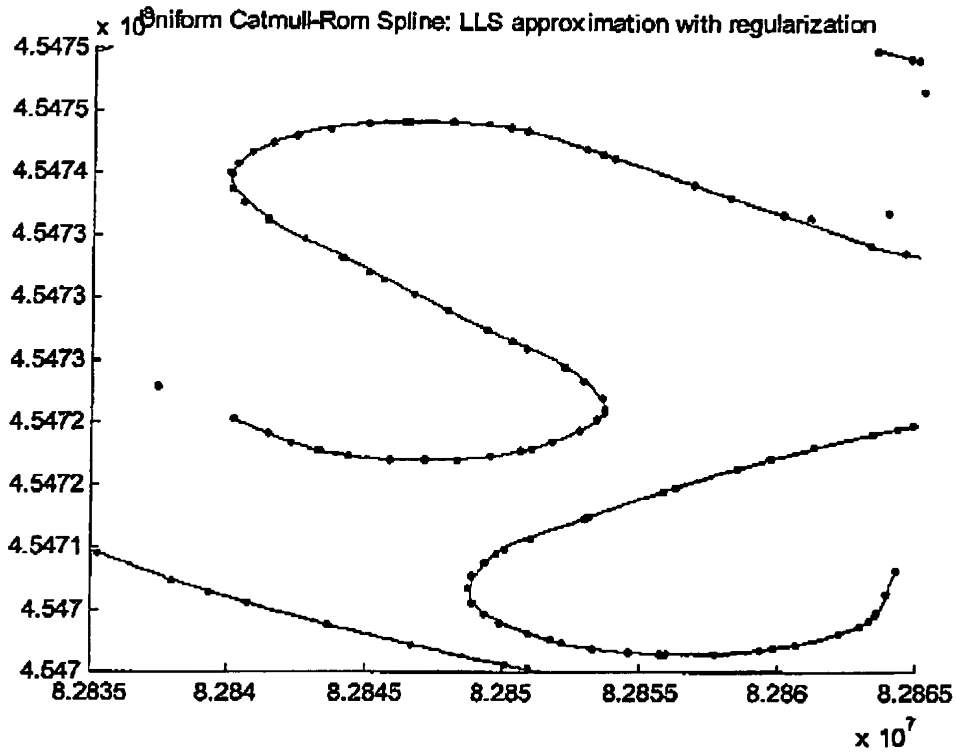

Figure 3

4. **Nonuniform B-spline LS fit Representation:** This method is similar to Method 1, but a Nonuniform B-spline is used. This method is more computationally intensive, and the resulting spline depends on not only a set of control points but also a set of parameters called knots, which must also be stored. However the nonuniform B-spline has the advantage that it has much more flexibility than the uniform B-spline and can be used to represent certain types of segments more accurately than the uniform B-splines. Example: See Figure 4.

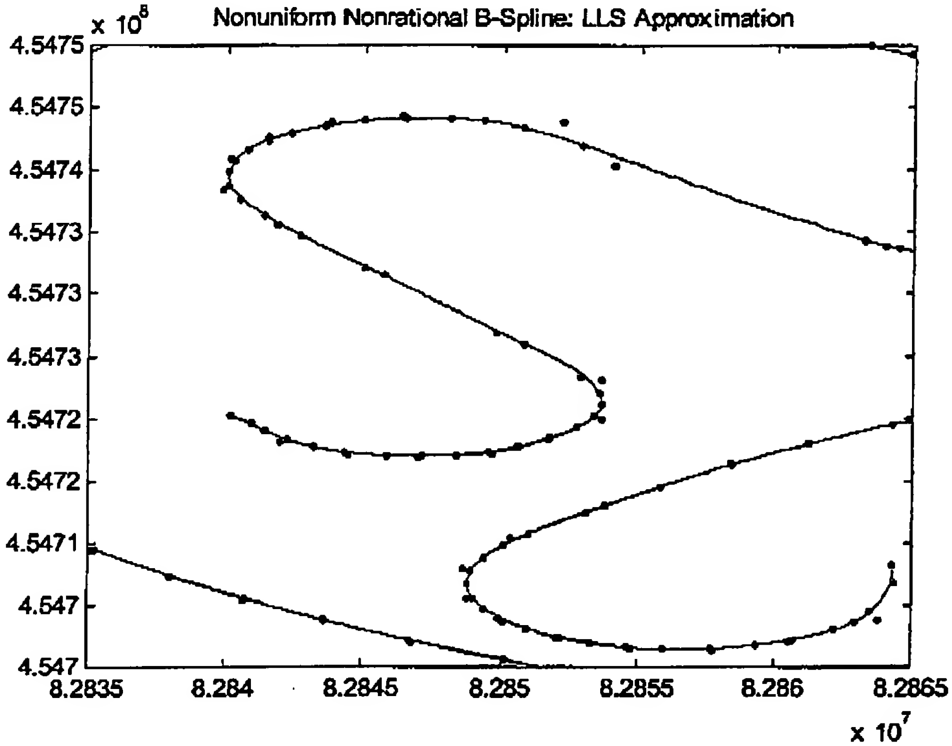

Figure 4